WT-1513

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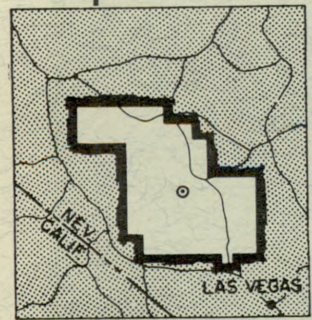
OPERATION
PLUMBBOB



NEVADA TEST SITE
MAY-OCTOBER 1957

Test Group 57, Program 74

SURFACE ALPHA MONITORING AS A METHOD OF MEASURING PLUTONIUM FALLOUT

Issuance Date: January 31, 1962

SANDIA CORPORATION
ALBUQUERQUE, NEW MEXICO

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WT-1513

Operation Plumbbob - Test Group 57, Program 74

SURFACE ALPHA MONITORING AS A METHOD OF MEASURING PLUTONIUM FALLOUT

By

R. E. Butler

and

H. M. Miller

Sandia Corporation
Albuquerque, New Mexico
August 1961

ABSTRACT

As one of a series of group efforts covering studies of radiation hazard resulting from one-point detonation of a weapon containing plutonium, this report gives a correlation as determined by chemical analysis of fallout between alpha survey meter readings and plutonium concentration in the immediate area of detonation. Results of determination of apparent decrease of surface contamination with time are presented. Also described is the training of personnel in the definition of radiation hazard following such accidental detonation. Maps of the test area show monitoring results in addition to isoconcentration contours.

FOREWORD

In this report activities of Program 74, one of four fostered by Test Group 57, are described. For full coverage of studies of fallout from one-point detonation of a weapon containing plutonium, the reader is referred to other reports in this series: WT-1510, WT-1511, and WT-1512.

ACKNOWLEDGMENTS

Appreciation is extended to the following: Dr. W. B. Leslie for conducting the training phase under field conditions; Dr. Leslie and Mr. R. M. Jacob for processing data and for assistance in preparing this report; Lt. Col. D. J. Gaston for freely offering his services in helping to organize personnel; Mr. F. Wilcox and the Reynolds Electrical and Engineering Company (REECO) Rad-Safe people for their assistance in training and operations; Mr. D. D. Myer and Mr. Everett Mathews for their cooperation and assistance in the training program; the Eberline Instrument Division of REECO for rushing their first production of Model PAC-1G to meet the deadline for Program 74; Mr. D. J. Coleman for an exceptional effort in discharging his responsibilities for instruments in this program; the monitors and staff for conscientious efforts; and to all others who aided in Program 74.

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SURFACE ALPHA MONITORING AS A METHOD OF MEASURING PLUTONIUM FALLOUT

1 INTRODUCTION

1.1 Objectives

The first purpose of this program was to correlate by chemical analysis alpha survey meter readings obtained on smooth hard surfaces with plutonium fallout concentrations in the immediate area of detonation; the second was to determine apparent decrease of contamination levels with time; the third purpose was to provide training of personnel in determining radiation hazards following an accidental nonnuclear detonation of a plutonium-bearing weapon.

1.2 Background

Monitoring with alpha survey meters is a practical method of promptly measuring the extent of contamination resulting from an accidental subcritical detonation of a weapon containing plutonium. Experimental data were needed, however, to correlate survey meter readings with actual amounts of surface contamination. This correlation is a function of the type of material contaminated. For example, meter readings on a graveled surface are smaller than those on a paved surface for the same concentration. The readings are also a function of particle-size distribution of fallout.

An accidental detonation in an urban area would be of much greater immediate concern than one occurring in a rural area. Smooth surfaces, i.e., sidewalks, curbing, pavements, and automobiles, are generally present in urban areas. The best correlation between survey readings and surface contamination can be expected from the monitoring of such surfaces. Accordingly, a standard broom-finish concrete surface was chosen to be monitored in this program. Two other types of surfaces were monitored extensively, since they were readily available in the field, i.e., soil and unpainted plywood.

When fallout from a one-point detonation first occurs, plutonium is deposited as a fine dust. Readings obtained with an alpha survey meter shortly after

detonation will be at a maximum. From this point the readings decrease with time. This "apparent" decrease in contamination level is caused by translocation of particles by the elements or by the addition of shielding material.

Because there were relatively few available people experienced in alpha field monitoring, a training program was set up in connection with Program 74 to train personnel who would form a nucleus of emergency teams stationed across the country and who would instruct others in problems and techniques of alpha monitoring in the field.

1.3 Theory

Estimates of the chronic hazard from plutonium depend upon knowledge of surface concentration. Readings from alpha survey meters are proportional to surface concentration. An alpha survey instrument can be calibrated with a source prepared by deposition of a known amount of plutonium uniformly in a very thin layer on a metal foil. A properly calibrated meter will give a reading in counts per minute equal to one-half the total number of disintegrations per minute occurring in the source (2π geometry). When a calibrated meter is used to determine the amount of plutonium fallout on a less ideal surface, irregularities of surface as well as nonuniformity and thickness of deposited plutonium must be taken into account.

There are 1.4×10^5 disintegrations per minute per microgram of plutonium. A probe of an area 60 centimeters square would be exposed to

$$\frac{1.4 \times 10^5}{2} \times \frac{60}{1 \times 10^4} = 4.2 \times 10^2 \text{ dpm} \qquad \text{(50 percent geometry)}$$

if placed on a surface of an ideally thin layer of plutonium of 1-microgram-per-square-meter concentration.

2 PROCEDURE

2.1 Description of Test Site

The test site was located in the Groom Lake area bounding the Nevada Test Site on the north. Total area of the site was about 100 square miles, of which approximately 70 square miles were instrumented for Test Group 57. About 20

square miles of the test area were instrumented for Program 74 as indicated in Fig. 1. General topography of the area can be seen in various illustrations included in this section. The test device was successfully one-point detonated at 0627 on April 24, 1957.

2.2 Survey Periods

To determine apparent decrease in surface contamination with time, Program 74 conducted resurveys of the area of interest at four different periods subsequent to D-Day. D-Day, as referred to in this report, includes operations conducted on D, D + 1, and D + 2 days. Resurveys were conducted during the following periods: W + 12 weeks, July 16-19, 1957; W + 24 weeks, October 8-11, 1957; Y + 1 year, April 14-19, 1958; and Y + 2 years, April 27-29, 1959.

2.3 Instrumentation

Monitoring surfaces. A broom-finish concrete surface representative of a typical urban sidewalk was chosen as the standard surface to be monitored. Approximately 1400 blocks, measuring 10 by 10 by 1 inch, were fabricated and arrayed in the test area prior to the shot. Zone A contained 24 blocks centered in 50-foot squares (Fig. 2). Zone B contained four blocks at every fourth grid intersection and one block at each of the other 250 grid intersections (Fig. 3). Zone C placement was variable and is shown in Fig. 1. Blocks were placed adjacent to fallout trays except in Zone A where blocks were placed next to stakes marking locations from which soil samples were later collected. A typical layout is depicted in Fig. 4.

Three clusters of blocks were placed on 500-foot centers in the northern part of Zone C as a means of estimating uniformity of fallout over a large area. Four blocks were placed at every fourth grid intersection in Zone B as a means of estimating uniformity of fallout over a smaller area. Each block surface was considered to have a left-hand area, a central area, and a right-hand area. These three areas in each block were monitored to estimate uniformity over a still smaller area (Fig. 5).

Two other types of surfaces, in addition to concrete, were monitored during resurveys conducted subsequent to D-Day. Readings were obtained on the tops of 24 by 24 inch unpainted plywood fallout tray stands, and on the surface of the soil adjacent to the concrete blocks.

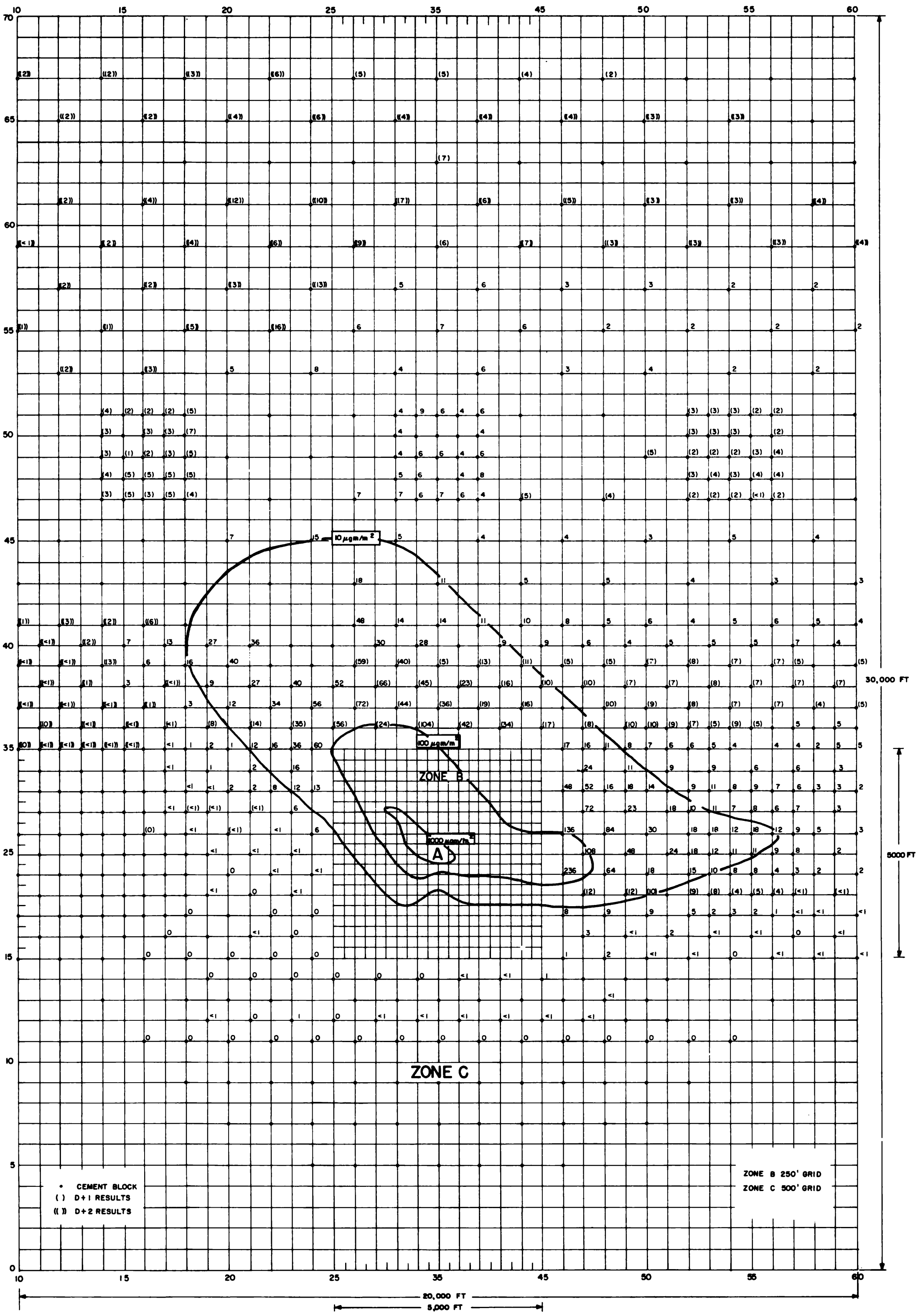

Fig. 1--Zones B and C alpha survey instrument results.

6700 352 491 170 180 E	4600 300 234 132 130 J	2600 197 185 76 64 O	1600 200 125 82 T	1800 96 76 38 21 Y
8000 700 1000 495 440 D	6600 336 356 144 140 I	5800 640 835 470 400 N	3500 292 210 S	2000 161 125 100 100 X
5400 480 370 184 185 C	7500 595 380 316 270 H	GROUND ⊙ ZERO	5300 234 245 226 213 R	5300 280 246 55 45 W
3800 366 221 136 118 B	6700 850 525 388 340 G	17000 1070 735 720 600 L	3200 206 205 138 96 Q	5600 294 229 132 143 V
4300 410 236 194 218 A	6000 772 705 476 510 F	5500 445 340 145 K	2000 116 91 124 104 P	2600 184 178 110 120 U

KEY

D- DAY*
W + 12
W + 24
Y + 1
Y + 2

* ADJUSTED FROM D + 2 MEASUREMENTS

Fig. 2--Zone A alpha survey instrument results.

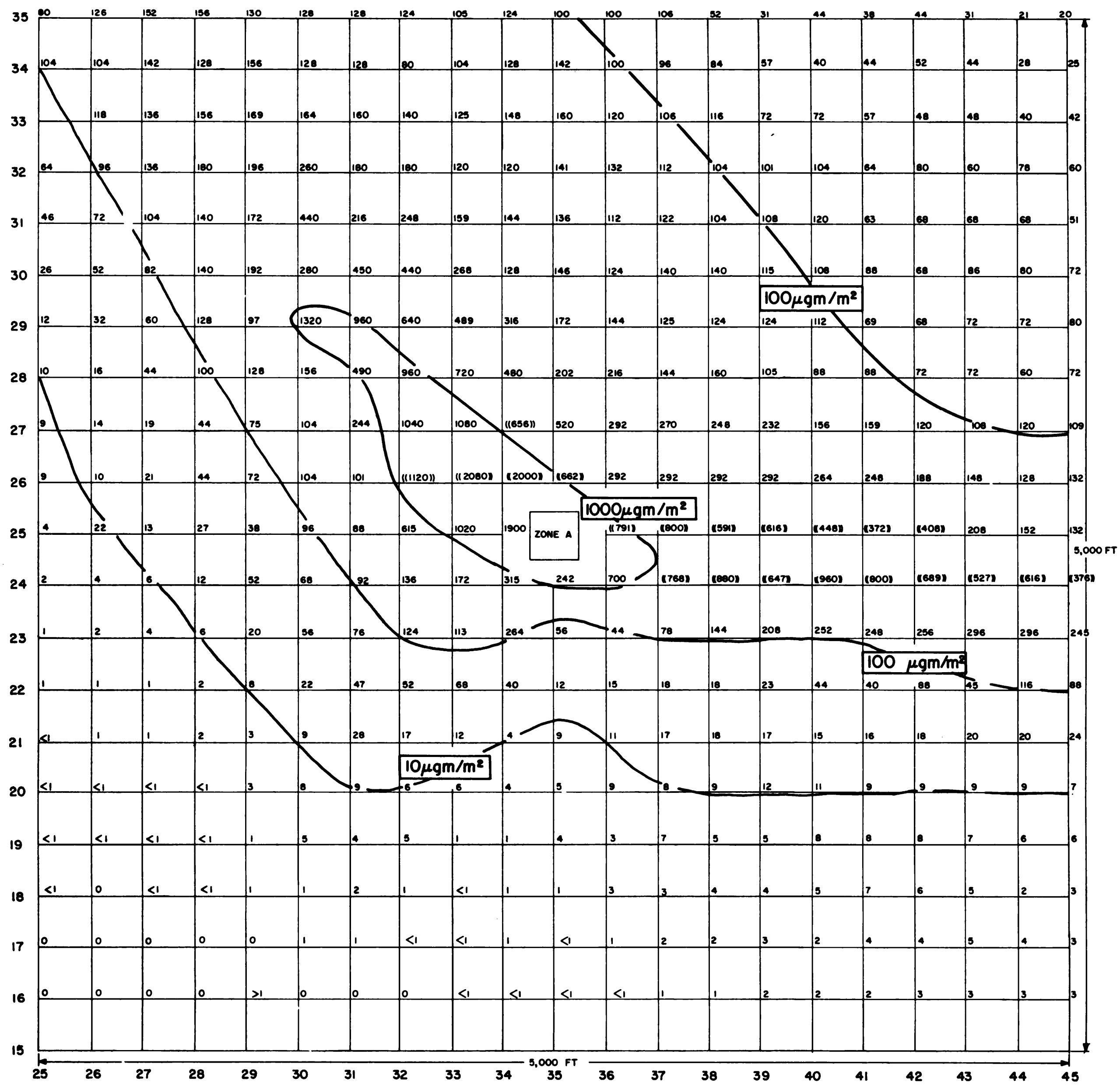

Fig. 3--Zone B alpha survey instrument results.

Fig. 4--Monitoring block at fallout pan station.

Fig. 5--Monitoring central area of block.

During the W + 24 resurvey, six uncontaminated concrete blocks were placed in Zone A. The blocks were monitored during the Y + 1 and Y + 2 resurveys to gain some idea of contaminate buildup on a clean surface located in a contaminated field.

Survey instruments. All Program 74 alpha monitoring was performed with Eberline Instrument Division Models PAC-1G and -2G gas-flow proportional counters. The two models differ only in the method of controlling gas flow. The PAC-2G is illustrated in Fig. 6. For the D-Day operation, Program 74 fabricated stands 1/4 inch high to which the probes were clipped in order to decrease possibility of contamination. The stands also acted to hold the probes a fixed distance from the surface monitored. Stands clipped on the far ends of the probes were provided with small disks containing sources of U^{235}. The source could be read by sliding the stand to a fixed position above the sensitive area of the probe. For resurveys conducted subsequent to D-Day, modified probes with deeper grillworks were used. These placed the probe screen farther from the surface monitored, thus eliminating the necessity for probe stands. However, the sliding disk source was retained and can be seen in place on the modified probe in the foreground in Fig. 6.

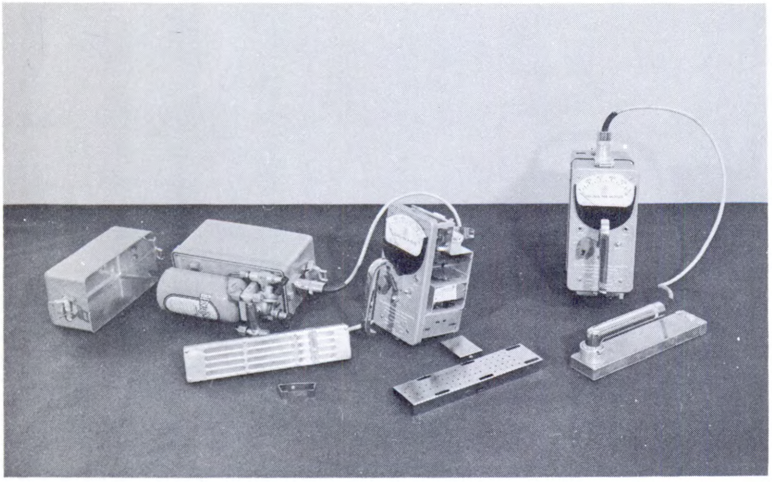

Fig. 6--Model PAC-2G alpha survey meter.

While being used in the test area, each counter was enclosed in a loose-fitting plastic bag with the cable taped. Because of these precautions, contamination of the survey instruments did not prove significant.

The maximum meter reading of the survey instruments was 100,000 cpm. In order to increase this range, a shield with a 1/4-inch-diameter hole was fixed over the sensitive area of the probe for some measurements taken on D + 2. Some

monitors on D-Day used a technique of placing only a fraction of the probe surface on the block and multiplying their readings accordingly. The probe was shielded from the nearby ground by use of a large envelope. An improved probe shield that increases the maximum range of the instrument by a factor of 20 has since been fabricated by Program 74 (Fig. 6). The shield is made of nickel-plated 0.020 inch brass stock into which 58 holes of 0.098-inch diameter are drilled. Slots are provided on the shield face to permit sliding of the disk source over the sensitive area of the probe.

Calibration. The primary alpha standard used in this experiment was a sheet of stainless steel having a very thin coating of plutonium on one side. As of March 4, 1957, this source (later called Pu source) was said to disintegrate at the rate of 580,000 dpm $\pm$ 10 percent. It is approximately 5 by 10 inches on a side and has a source area of 324 cm^2.

The secondary alpha standard, a disk coated with U^{235}, could be mounted in a jig that held it in a fixed position relative to every probe. This source was designated S-4. The ratio of instrument response to the Pu source and to the S-4 source was determined.

Finally, a tertiary standard, described above under the paragraph devoted to survey instruments, was allied to each instrument. The response of each instrument to the S-4 source and its tertiary standard (spot source) was determined at the beginning of each day of use. Thereafter, the response of each instrument to its spot source was determined prior to each series of readings at each station in the field.

Subsequent to the W + 24 resurvey, the ratio of instrument response to the Pu source and each spot source was determined. Consequently, during the Y + 1 and Y + 2 resurveys, the spot sources served the function of the secondary standard, thus eliminating the need for the S-4 source.

2.4 Operations Plan

Because of personal discomfort and lowered efficiency from wearing protective equipment, and because of the rather large number of people to be trained in field monitoring, two shifts of personnel were organized into teams according to areas to be monitored on D-Day. Zone B was divided into four quadrants, with

one team assigned to each quadrant. Zone C was divided into three parts, with six teams assigned to that zone. Zone B monitors worked on foot in their assigned areas (Fig. 7). Each Zone C team used a vehicle, and team members alternated between driving and monitoring. Similar operational plans were followed during subsequent resurveys.

Protective clothing for each individual consisted of coveralls, two pairs of booties, surgeon's cap, and goat skin gloves. Openings in the clothing and interfaces were taped after donning of clothing. Wilson full-face gas masks, Type WHG-DFM, were worn by personnel working in Zone B (Fig. 7); personnel in Zone C wore MSA Comfo Ultra Filter respirators.

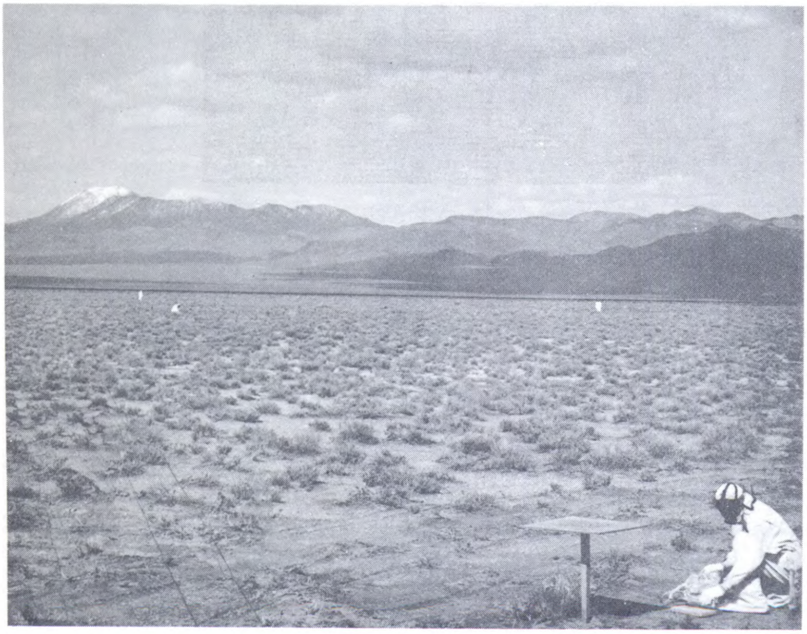

Fig. 7--Monitoring in Zone B.

A decontamination station manned by Reynolds Electrical and Engineering Company (REECO) personnel provided protective equipment for area entry, clothing disposal on exit, shower baths, and monitoring to assure freedom from contamination before donning of personal clothing. Also, air samplers were operated continually to check environs for contaminant buildup.

To facilitate the monitoring operation, special data card holders were fabricated for Zone B monitors. The holder consisted of a 3- by 5-inch sheet of aluminum for backing, a large alligator clip for attaching the holder to the monitor's coveralls, and a pencil holder. Printed data cards were prearranged in each monitor's holder. The data holder is shown being worn on the left leg of the monitor in Fig. 8. Printed data sheets held in ordinary clip boards were used by Zone C monitors.

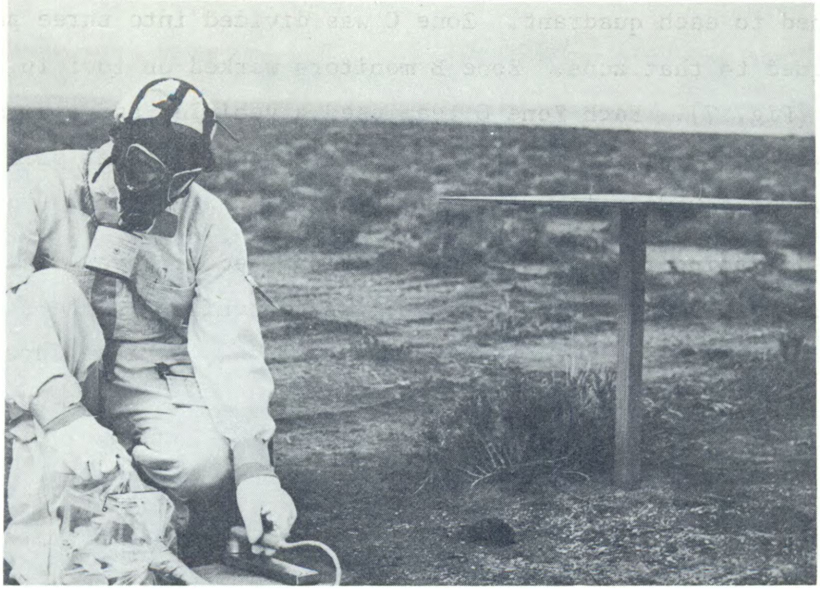

Fig. 8.--Zone B monitor.

Zone B monitors were required to pick up fallout collectors at each station monitored. These collectors, called "sticky pans," were 9- by 9-inch sheets of galvanized steel sprayed on the top side with alkyd resin in toluene. Pickup procedure consisted of dropping a clean cover pan on the sticky pan and slipping the pair into an envelope. The monitor shown in Fig. 7 has hanging from his left hip a strap-on bag used for carrying the pans.

Trailer space was available in which radio contact could be maintained between the Program Director and monitoring teams. Data could be recorded and plotted. Space was also assigned for instrument maintenance and calibration.

Seven radio-equipped vehicles were assigned at H + 2 on D-Day for use in the contaminated area. Two "clean" vehicles were used throughout the operation by Program 74 for administrative purposes.

Of the twenty survey instruments purchased for this program, no fewer than eighteen instruments were always operational; usually all twenty were available. From the first planned D-Day, April 10, until actual D + 2, April 26, all survey instruments were left turned on. Probes were flushed with gas and a steady gas flow was established at least two hours before instruments were to be used. Each instrument was checked against the standard source, S-4, and against its

tertiary source prior to issue to monitors. These preparations resulted in excellent instrument performance in the field.

Data cards and sheets were passed by the monitors across the "hot-cold" boundary at the decontamination station. A data handler on the cold side accepted the data between transparent plastic sheets. The edges of the sheets were than taped together so that original data could be handled without personnel becoming contaminated. Data cards and sheets were then taken to the control point where a running plot of estimated isoconcentration contour was maintained. This early information on fallout was of considerable interest to all programs. To insure against loss, all field data were transcribed into notebooks as soon after receipt as possible.

2.5 Calculation of Isoconcentration Contours

Normalization of survey readings. It was not feasible to maintain each alpha survey instrument at the same level of detection efficiency. Thus, survey readings from different instruments had to be normalized to a common standard before comparison; calibration procedures have been discussed above. Normalization is made to 50 percent (2π geometry) of the total disintegration per minute per probe area of the Pu source already described. That is, field readings from an instrument are normalized to values that would have been obtained had the instrument response been adjusted to give a reading equal to 50 percent of total disintegrations per minute per probe area of a thin Pu foil, with the probe placed on the foil in the same geometry as used in the field. The method used for normalization of survey readings to a common standard varied slightly following each of the resurveys. This was due partly to the change in instrument probe construction prior to the W + 12 resurvey. Also, greater emphasis was placed on field spot source readings after the D-Day operation. Readings are normalized as follows:

D-DAY, D + 1, AND D + 2

Probe clip-on stands in place for readings on block and readings on Pu.

$$(\text{block count})_{\text{norm}} = \left(\frac{\text{block count}}{\text{spot source count}}\right)_{\text{field}} \times \left(\frac{\text{spot source count}}{\text{S-4 source count}}\right)_{\text{check}}$$

$$\times \left(\frac{\text{S-4 source count}}{\text{Pu source count}}\right)_{\text{lab}} \times \left(\frac{\text{total dpm Pu source}}{\text{source area x 2}} \text{ x probe area}\right).$$

Putting in constants, the result is:

$$(\text{block count})_{\text{norm}} = \left(\frac{\text{block count}}{\text{spot source count}}\right)_{\text{field}} \times \left(\frac{\text{spot source count}}{\text{S-4 source count}}\right)_{\text{check}}$$

$$\times \left(\frac{47,000}{65,000}\right) \times \left(\frac{580,000}{324 \times 2} \times 61\right) \quad .$$

$$(\text{block count})_{\text{norm}} = 40,000 \times \left(\frac{\text{spot source count}}{\text{S-4 source count}}\right)_{\text{check}} \times \left(\frac{\text{block count}}{\text{spot source count}}\right)_{\text{field}}$$

or,

$$(\text{block count})_{\text{norm}} = (\text{normalization factor})\ (\text{block count}) \quad .$$

W + 12

Use of a probe of deeper grillwork resulted in the ratio:

$$\frac{(\text{S-4 source count})}{(\text{Pu source count})}_{\text{lab}} = \frac{33,000}{52,000} \quad ,$$

or,

$$(\text{block count})_{\text{norm}} = 35,000 \times \frac{(\text{spot source count})}{(\text{S-4 source count})}_{\text{check}}$$

$$\times \frac{(\text{block count})}{(\text{spot source count})}_{\text{field}} \quad .$$

W + 24

An average value of S-4 and spot source readings was determined for each instrument and for each day.

Y + 1 AND Y + 2

Prior to the Y + 1 resurvey, the spot source was directly related to the Pu source, thus eliminating the requirement for the S-4 source. Consequently, Y + 1 readings were normalized by using the spot source as the standard as follows:

$$(\text{block count})_{\text{norm}} = \text{block count} \times \frac{(\text{spot source count})\ \text{check}}{(\text{spot source count})\ \text{field}}$$

Conversion of survey readings to plutonium concentrations. Data derived from radiochemical analysis of each fallout tray eventually provided information for the drawing of isoconcentration contours throughout the field. However, since many programs and agencies desired guiding contours as soon as possible after the shot, contours were drawn which used survey readings converted to Pu concentrations on the basis of the following assumption: Self-absorption of alpha particles in Pu oxide fallout and reduction in geometry due to roughness of cement surfaces result in survey readings about one-third of those which would be obtained from an ideally thin layer of the same concentration (420 d/m, 50-percent geometry). Thus, it was assumed that 140 cpm read on a concrete block corresponds to a surface concentration of 1 $\mu gm/m^2$. Using this conversion and integrating the fallout over the area around ground zero out to the 10 $\mu gm/m^2$ contour led to the conclusion that about 60 percent of the original plutonium fell out in this area. Contours drawn on the basis of fallout-tray radiochemistry results indicate that the percentage of original plutonium contained within the 10 $\mu gm/m^2$ contour should be closer to 30 percent. A comparison of contours uncovered differences of a factor of 2 in enclosed areas. It remained a relatively simple matter to adjust survey data to produce contours which agree satisfactorily with those from chemical data. The conversion factor of 140 cpm per $\mu gm/m^2$ utilized for preliminary conversion was increased to 250 cpm per $\mu gm/m^2$. It must be remembered that this conversion factor of 250 cpm/$\mu gm/m^2$ applies only to count-rate readings obtained from fresh plutonium on broom-finished concrete with the Eberline PAC instrument probe resting on the surface.

A graph was constructed for each grid line in both north-south and east-west directions showing concentration versus distance along the line. A typical

graph is shown in Fig. 9. This method permits estimation of concentrations at points in the field for which survey data are not available and aids in determining relative positions of isoconcentration contours.

2.6 Training

A total of 98 people received training in connection with Program 74: 40 from Sandia Corporation, 29 from various DOD agencies, and 29 from the AEC and AEC contractors. The DOD agencies included the U.S. Army Chemical and Ordnance Commands, the Defense Atomic Support Agency, and the Strategic Air Command. Also, U.S. Air Force Explosive Ordnance Disposal personnel from eleven Air Force bases located throughout the country. The AEC agencies included Brookhaven National Laboratory, Argonne National Laboratory, Hanford, Rocky Flats, Mound Laboratory, Mason and Hanger, Pantex, and the New York Operations Office.

The two main objectives of the training program were to prepare personnel (1) for monitoring in Test Program 74 and (2) for training other personnel required for emergency teams. The training program consisted of lectures, field work, and a study assignment (Appendix A). A field training exercise was conducted during the Y + 1 resurvey to determine how accurately a small number of monitors can delineate contour lines. The majority of trainees who participated in the exercise had very little if any previous field alpha survey experience. Seven teams, each composed of four to eight monitors, were briefed on the general location of the contamination and were supplied with grid maps on which to record their survey readings. Each team then drew a 10 $\mu gm/m^2$ contour based on their field measurements. The favorable results can be seen by comparison of the boundaries of the training contours with the 10 $\mu gm/m^2$ contour carefully established by systematic monitoring of the same area a few days later (Fig. 10).

Some personnel attended a training course at Los Alamos Scientific Laboratory during the week of April 1, 1957, prior to reporting to Camp Mercury. This training was duplicated, in many cases with different lecturers, at Mercury. Therefore, LASL trainees did not attend all the lectures. Also, LASL trainees were under LASL direction during the field exercise conducted in Area 11, an area previously contaminated from one-point detonation tests in 1955-56 (Project 56).

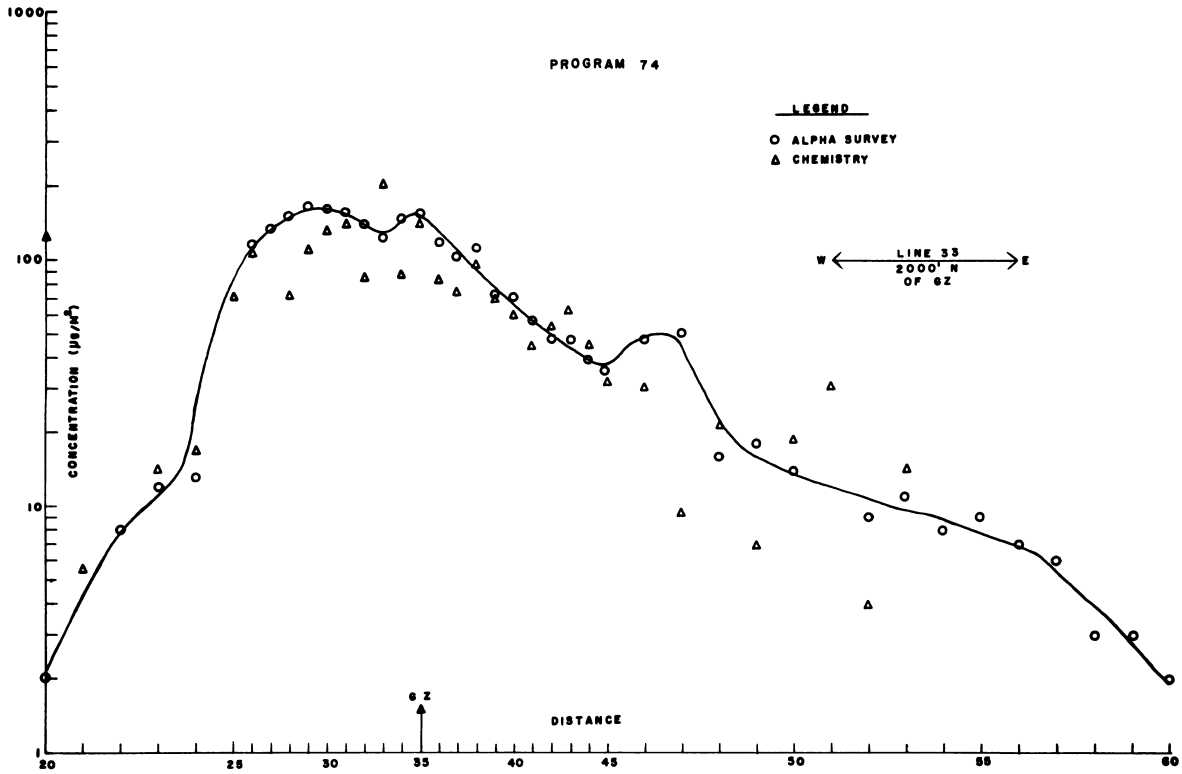

Fig. 9--Concentration versus distance.

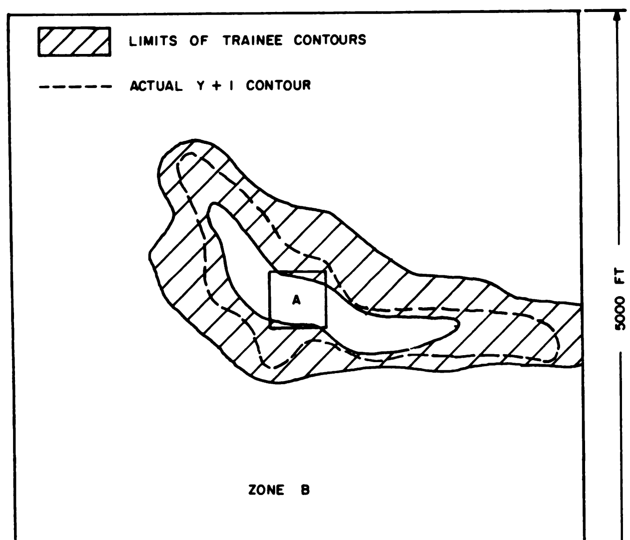

Fig. 10--Field contour training exercise results.

3 PRESENTATION OF DATA

3.1 Calculations

The three alpha readings on each block were averaged arithmetically, then corrected for background, provided the background was greater than 5 percent of the average. Finally, the corrected average was normalized according to procedure discussed above in the paragraph devoted to normalization of survey readings in Section 2.5. For D-Day data, an average field spot source count for each monitor was calculated. Thus, one normalization factor was determined for each monitor's trip into the field. Since greater emphasis was placed on spot source readings made during later resurveys, the spot source reading taken before each set of three block readings was considered individually in calculating a normalized reading for each block.

3.2 Normalized Data

D-Day monitor data are contained in Figs. 1, 2, and 3. The amount of plutonium fallout in the area enclosed by the 10 $\mu gm/m^2$ contour was determined by graphical integration to be 33 percent of the original amount. The amount contained between each contour was as follows:

Contour ($\mu gm/m^2$)	Plutonium (%)	
GZ - 3500	2	
3500 - 1000	6	
1000 - 100	16	
100 - 10	9	
	33	Total

3.3 Isoconcentration Contours

Isoconcentration contours are shown in Figs. 1 and 3. A graphic representation of concentration versus area based on measurements made with a planimeter is shown in Fig. 11. Comparison of Program 71 and Program 74 contours is depicted in Fig. 12.

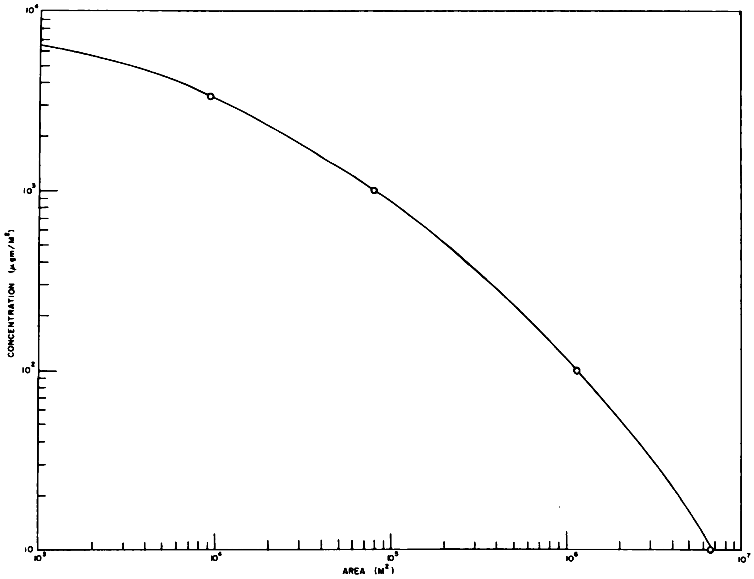

Fig. 11--Concentration versus area.

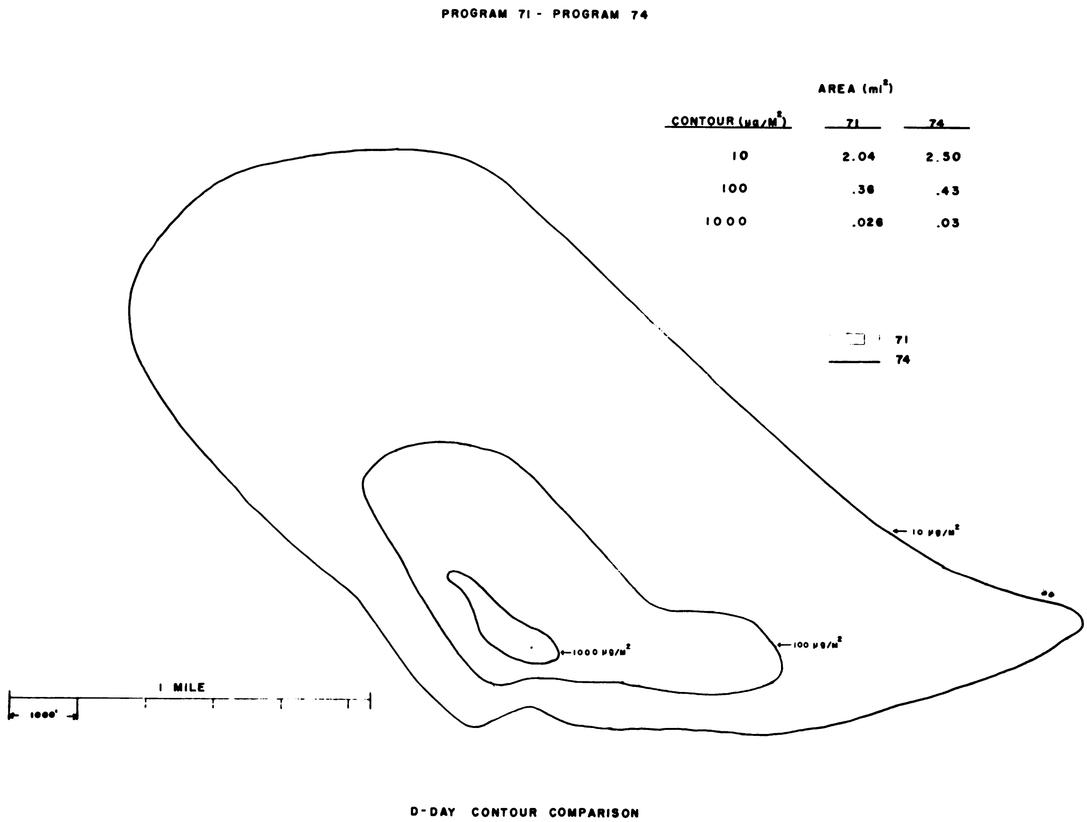

Fig. 12--D-Day contour comparison.

Major contours enclose areas around ground zero as follows:

Contour ($\mu gm/m^2$)	Area enclosed (sq mi) Program 74	Program 71
3500	0.003	
1000	0.03	0.026
100	0.43	0.36
10	2.50	2.04

Radii of circles enclosing equivalent areas are calculated:

Program 74 Contour ($\mu gm/m^2$)	Radius (ft)
3500	165
1000	500
100	2000
10	4700

Maximum distances from ground zero to each contour are:

Program 74 Contour ($\mu gm/m^2$)	Distance (ft)
3500	300
1000	1700
100	4000
10	8500

3.4 Readings on Other Surfaces

The primary effort in this experiment was to correlate survey readings of a standard surface (concrete) with actual contamination of that surface. Some readings were taken, however, on other surfaces, e.g., plywood and ground. A comparison of readings obtained from these two surfaces with concrete block readings at the same location revealed the following conversion factors:

Nevada soil, 200 cpm per $\mu gm/m^2$

Unpainted plywood, 300 cpm per $\mu gm/m^2$

3.5 Degradation Factors

Readings taken on D + 1 and D + 2 must be considered as degraded because of weathering of the blocks. Some blocks read on D-Day were read again on D + 1 or D + 2 to establish a basis for tying in the other data taken on later days. The ratio of a repeat count to the original count is the degradation factor prior to conversion to concentration. Such results are indicated by inclusion in parentheses in Figs. 1 and 3. Apparent degradation during later resurveys is expressed as the ratio of D-Day concentration to concentration at a later date. Degradation factors were determined for each of the three types of surfaces monitored at each station. An average degradation factor was then calculated for each surface over the entire area monitored during the later resurveys. Experimental points for the three types of surfaces monitored are plotted in Fig. 13, together with estimated degradation curves to D-Day plus two years.

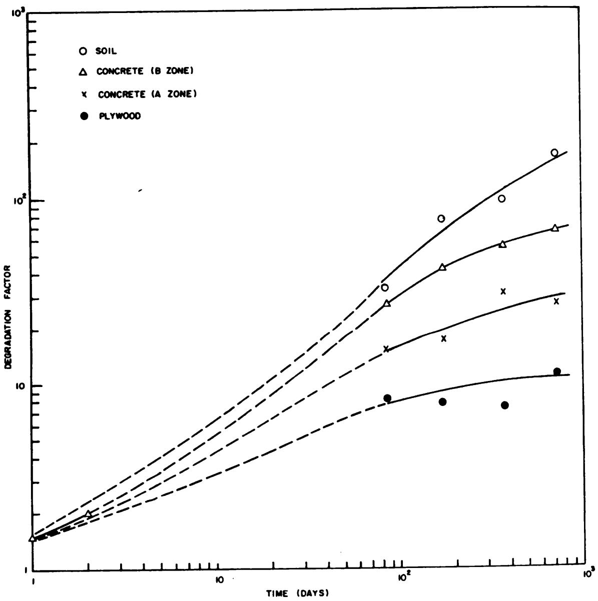

Fig. 13--Apparent degradation curves.

3.6 Precision of Data

A field exercise was conducted during the W + 24 resurvey to determine probable error of field survey readings contained in this report. Eight monitors, each equipped with a PAC instrument, made three readings on each of 22 concrete blocks of varying intensities. Results derived from statistical analysis of the data are given in Fig. 14. As can be seen from the graphs, the average of three readings obtained from a single block lies with $\pm$ 17 to 34 percent of the true average value (based on a 95-percent confidence factor). Increase in error with increasing instrument sensitivity was caused primarily by difficulty in reading the large meter fluctuations inherent in the lower scales of the instrument.

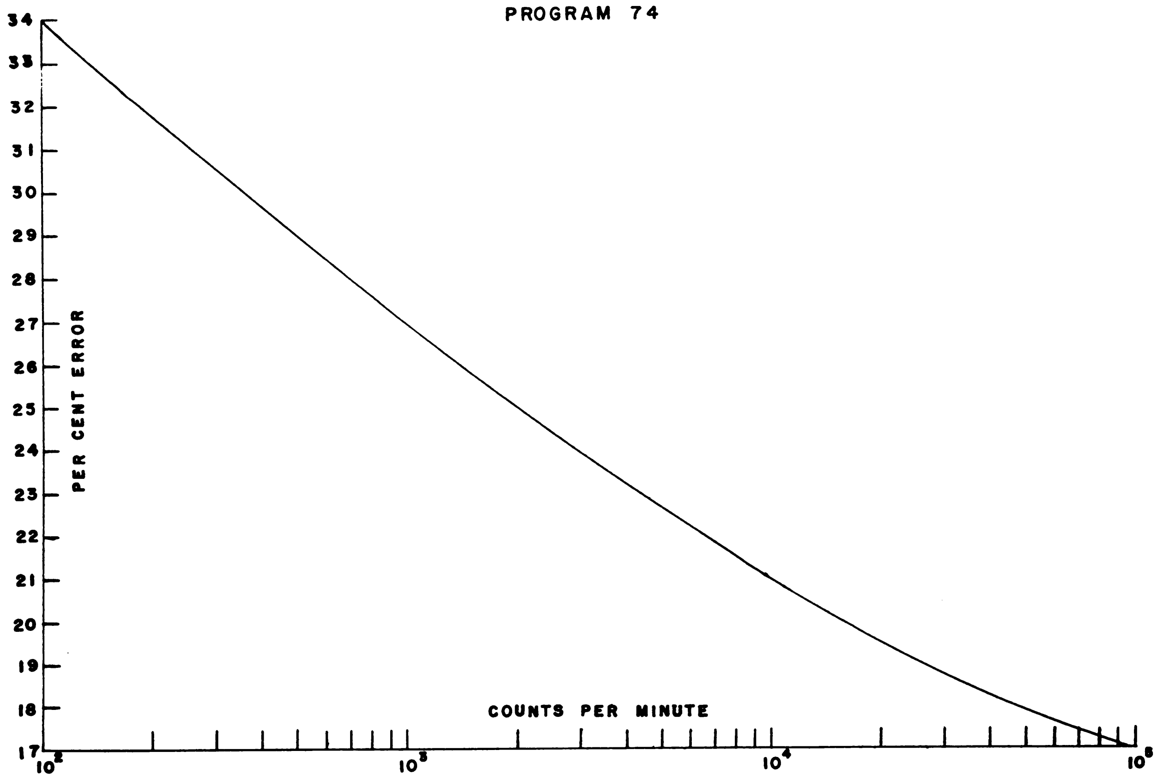

Fig. 14--Count rate versus percent error.

3.7 Topographical Model

A three-dimensional model of part of the fallout field was constructed by conversion of D-Day surface concentrations to heights on a log scale above a base plane (Fig 15). Specifically, the 2.5-inch level represents a concentration of 10 $\mu gm/m^2$ or less; the 12.5-inch level represents a concentration of 100 $\mu gm/m^2$; the 22.5-inch level represents a concentration of 1000 $\mu gm/m^2$; and the 32.5-inch level represents a concentration of about 10,000 $\mu gm/m^2$ (the average concentration in Zone A). Location of the 3500 $\mu gm/m^2$ contour, representing an area of approximately 0.003 square mile, is also shown.

3.8 Concrete Block Autoradiograph

Several autoradiographs of concrete blocks were obtained by 48-hour exposure of Kodak medical x-ray film. A typical autoradiograph is shown in Fig. 16. Exposures were made on blocks taken from the test field during the W + 24 re-survey. Since the blocks had undergone six months of weathering, they should not be considered typical of indication of fresh plutonium fallout. However,

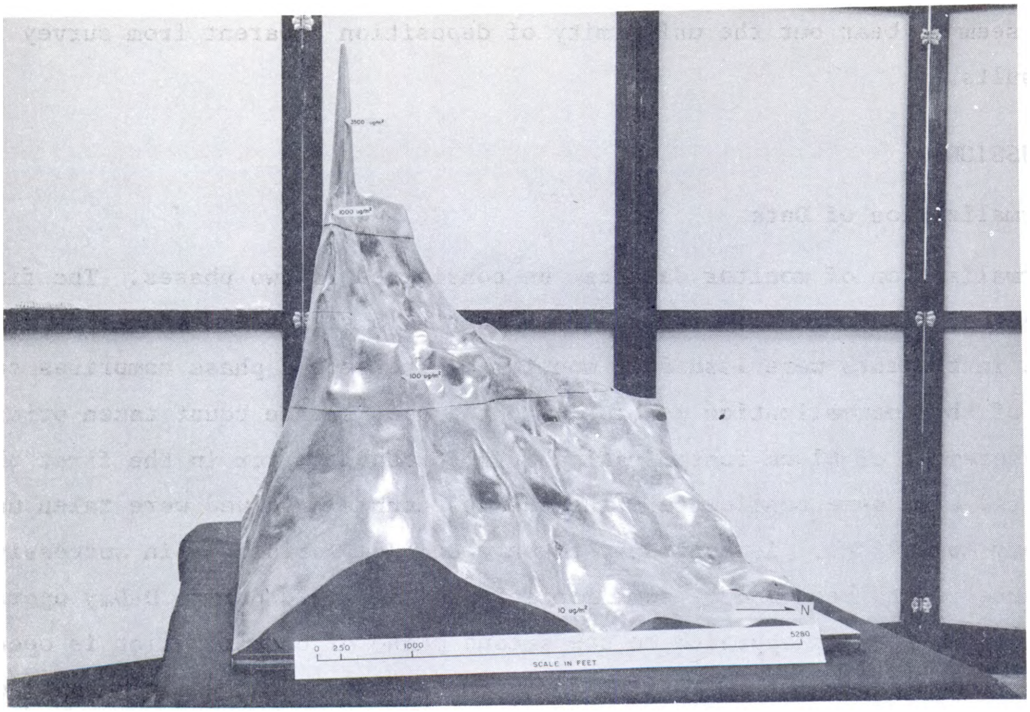

Fig. 15--Topographical model.

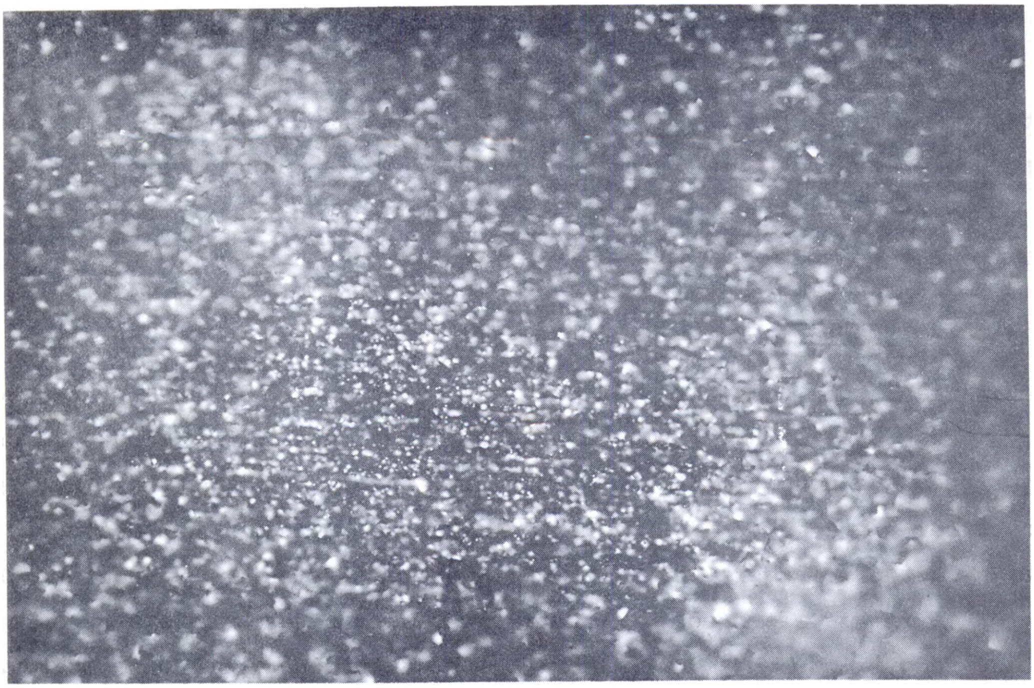

Fig. 16--Concrete block autoradiograph.

results seem to bear out the uniformity of deposition apparent from survey instrument results.

4 DISCUSSION

4.1 Normalization of Data

Normalization of monitor data can be considered in two phases. The first comprises normalization of instrument readings to a standard response at the time the instruments were issued to monitors. The second phase comprises correction of this normalization according to the spot source count taken prior to each measurement of block contamination. The probable error in the first phase is accepted with some confidence, since source counts involved were taken under laboratory conditions. In contrast, there were wide variations in successive spot source counts recorded by some monitors in the field during D-Day operations, and the correct approach to the second phase of normalization is open to question. There is evidence that most monitors considered the field spot source count as simply a rough check to determine that their survey instrument was still working "properly." On this basis, it does not appear reasonable to modify drastically the carefully obtained block readings because of casually obtained source readings. Therefore, average spot source field counts for monitors and their instruments rather than individual source counts to correct each associated block reading were used in normalizing their data. The PAC-1G appears to have a very stable response, and averaging by this method is probably suitable. On resurveys conducted subsequent to D-Day, the importance of field source counts was stressed so that individual source counts could be used to correct each associated block reading.

4.2 Degradation Factors

Insufficient time allowance for driving over rough terrain prevented complete coverage of Zone C on D-Day. As a result, on D + 1, not enough emphasis was placed on repeating measurements made on D-Day. It is apparent that the degradation factor for D + 1 is not very consistent, and it is not clear whether a true degradation factor to cover the entire 20 square miles monitored should exist. Beginning late in the afternoon of D-Day, the test area was subjected to rain squalls and gusty winds. Data are too scant to determine whether weather was uniform over the area; visual observations indicate that it was not. Similar

uncertainties exist about data taken on D + 2. Data taken only on D-Day were used in correlation with chemical results; sufficient data were taken on D-Day to satisfy the main purpose of Program 74.

4.3 Uniformity of Fallout

It is concluded that fallout was remarkably uniform over the area of concrete blocks and over the area represented by four-block clusters. Fallout appears to have been smoothly decreasing with distance from ground zero, with larger concentrations toward the northwest and to the east. Three clusters of 25 blocks each in the northern part of Zone C appeared to be evenly contaminated.

4.4 Contaminate Buildup

As indicated in the first paragraph (monitoring surfaces) of Section 2.3, six uncontaminated concrete blocks were placed on the ground in Zone A during the W + 24 resurvey for the study of contaminate buildup on a clean surface. The "clean" blocks and the surrounding areas were then monitored during the Y + 1 and Y + 2 resurveys. Analysis of results indicates buildup of contamination on the "clean" surface to about 5 percent of apparent contamination of the surrounding area during the period W + 24 to Y + 1. Vehicular disturbance in Zone A precluded accurate determination of contamination on the same "clean" blocks which occurred during the period Y + 1 to Y + 2. Generally, there appeared to be an increase of a few percent over concentrations measured during the Y + 1 resurvey.

5 CONCLUSIONS AND RECOMMENDATIONS

It is feasible to determine isoconcentration contours of plutonium fallout by surveying with portable alpha monitoring instruments. However, corrections must be made for different surfaces measured, and all measurements must be made within a short time without intervention of gusty winds or precipitation.

One-point detonation of the device used in this experiment, where the device lies unrestricted on the ground, results in rather uniform plutonium fallout under mild wind conditions.

Establishment of grid lines of expanding dimensions out from ground zero and the monitoring of smooth surfaces present near grid intersections have been demonstrated as a feasible method of conducting an alpha survey of a contaminated

area. It has additionally been demonstrated that a large number of trained monitors, as many as twenty or thirty, should be dispatched to the scene as soon after an accident as possible. It is suggested that monitors be organized in teams of about five people and assigned specific sectors to monitor.

APPENDIX A TRAINING PROGRAM
Training Director--W. B. Leslie

A.1 Lectures

Subject	Speaker
Radiation Safety Procedures for Working in Highly Contaminated Plutonium Fields	F. W. Wilcox, REECO
Background and Objectives of Program 74 (Surface Alpha Monitoring)	R. E. Butler, SC
Program 74 Monitoring Plan	H. M. Miller, SC
Physiology of Plutonium	W. B. Leslie, SC
Instruction for the Use of the Model PAC-1G Alpha Monitor	D. J. Coleman, SC
Fundamental Principles of Portable Alpha Monitoring Instruments	W. B. Leslie, SC
Objectives for a Plan for Handling a Plutonium Contamination Accident	R. E. Butler, SC W. B. Leslie, SC
(Classified subject)	Col. E. A. Pinson, AFSWC
Background and Objectives of Program 73 (Decontamination)	Maj. J. L. Dick, AFSWC
Background and Objectives of Program 72 (Biomedical)	J. N. Stannard, U. of Rochester
Monitoring of Airborne Plutonium	E. Hyatt, LASL
Twelve Years Experience with Plutonium Contamination Problems	D. D. Meyer, LASL
Urine Analysis as a Measure of Plutonium Body Burden	D. D. Meyer, LASL
Respiratory Protection	E. Hyatt, LASL
Disposal of Plutonium-Contaminated Waste	E. R. Mathews, ALOO
Biological Effects of X-Rays	W. B. Leslie, SC
(Classified subject)	W. B. Leslie, SC
Control of Polonium Contamination	H. E. Meyers, Mound Lab
Objectives of Test Group 57	J. D. Shreve, Jr., SC
Concepts for Radiation Exposure and Shelter in Wartime	Col. E. A. Pinson, AFSWC
Radiation Dosimetry	K. P. O'Brien, NYOO

A.2 Monitoring Exercise

Assignment. Prepare a rough contamination-level map of "Area 11-C" within a period of one hour after entering the area. Area 11-C is the site of a one-point detonation that occurred 1-1/2 years ago. Do not approach nearer than 100 feet of ground zero.

Procedure.

1. Prepare a blank grid map of an area 1,200 feet square (Scale: 1 inch = 100 feet).

2. Each of the four teams will approach ground zero from a different cardinal point of the compass. Preliminary measurements of ground contamination should be made as each team proceeds.

3. Circle ground zero in an expanding circular path until enough measurements have been made to estimate the rough direction of cloud travel.

4. Fill in the map, marking instrument readings on the map in units of micrograms/square meter. Be concerned only with the most highly contaminated areas.

5. Plot the 100-microgram/square meter contour line and any other significant contours, such as highly contaminated object in the area.

NOTE: For soil in this area, assume that 20 c/m = 1 microgram/square meter.

A.3 Study Assignment

Prepare a detailed "Operation Plan for Handling the Plutonium Contamination Problem resulting from Accidental Detonation of a Weapon." The plan should be prepared in outline form and should cover the following phases:

1. Phase I - The Immediate Problem (H to H + 8 hours)

2. Phase II - Evaluation and Action (H + 8 to D + 5 days)

3. Phase III - Evaluation and Action (D + 5 days to Y + 100 years)

The plan should cover the specific case below:

1. The accident is to occur in the railroad switching yards of a city with a population of 20,000.

2. In the immediate vicinity are the electric utility company, railroad offices, a railroad trunk line, a moderate-income residential area, a turnpike,

a clothing manufacturer having a large parking area in the environs of the factory, and a river which is the sole water source for a nearby downstream city.